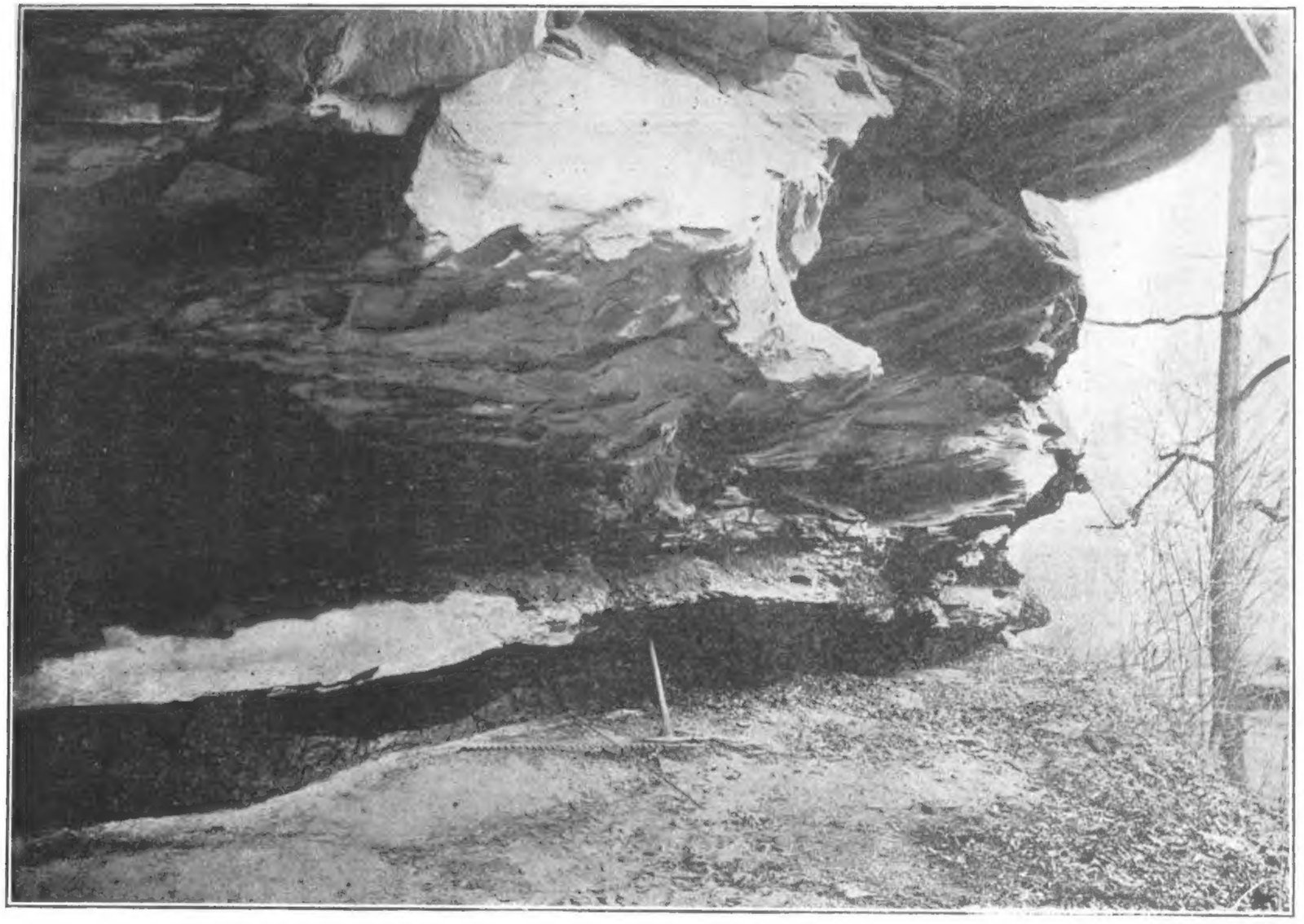
The

Kentucky Geological Survey

WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST

SERIES SIX
VOLUME SIX

The Sixth
Geological Survey
1921



THE WHITESBURG COAL AND SANDSTONE "ROCKHOUSE" ROOF.

This characteristic view of the well known Whitesburg coal and its superimposed thirty feet of cliff forming sandstone may be seen on Otter Creek just above its juncture with the Middle Fork of the Kentucky River in Perry County.

THE
SIXTH GEOLOGICAL SURVEY

An Administrative Report of the Several Mineral Resource and General Geological Investigations Undertaken and Completed in Kentucky during the Biennial Period 1920-1921

By

WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST

PRESENTED WITH TEN SEPARATE MISCELLANEOUS GEOLOGICAL PAPERS

BY

GEORGE P. MERRILL,
STUART WELLER
WILLARD ROUSE JILLSON
STUART ST. CLAIR
AND
CHARLES STEVENS CROUSE

Illustrated with 101 Photographs Maps and Diagrams

First Edition

1,000 Copies

THE KENTUCKY GEOLOGICAL SURVEY
FRANKFORT, KY.
1921

THE STATE JOURNAL COMPANY
Printer to the Commonwealth
Frankfort, Ky.

PREFACE

Applied geology is of great economic value to every State in which natural resources are only partly developed. This is especially true of Kentucky where the great body of mineral resources are now less than 20% under commercial operation. An ideal arrangement would be one where the State would have completed the base (topographic) mapping and the preliminary geological-resource surveys prior to the opening up of any oil, coal, natural gas, asphalt or other field. During the period of proving up such a field, State employed geologists could well work hand in hand with the operators, and assist them greatly in their efforts to win the resources desired.

Unfortunately this ideal arrangement has never existed in Kentucky, though it has to some extent in other States. With only 46% of Kentucky base (topographic) mapped, and with an area approximating that of sixty counties not covered by any accurate maps at all, the function of the Kentucky Geological Survey has always been crippled and held in restraint. The day of a 100% efficiency of the Kentucky Geological Survey seems yet to be in the distant future.

During the last biennium a large number of subjects of great economic value to this State have been investigated, however, by the Kentucky Geological Survey. A full account of these investigations is presented herewith in the first paper of this volume entitled, "The Sixth Geological Survey." A number of these economic papers are included within the covers of this book, and should assist materially in an understanding of the geology and resources of the several regions covered. This report is issued in an original edition of one thousand copies.

W. R. Jillson

Director and State Geologist.

Old Capitol,
Frankfort, Kentucky.
December 15, 1921.

CONTENTS

ILLUSTRATIONS

THE SIXTH
GEOLOGICAL SURVEY

IV

THE
OIL POOLS OF WARREN COUNTY, KY.*

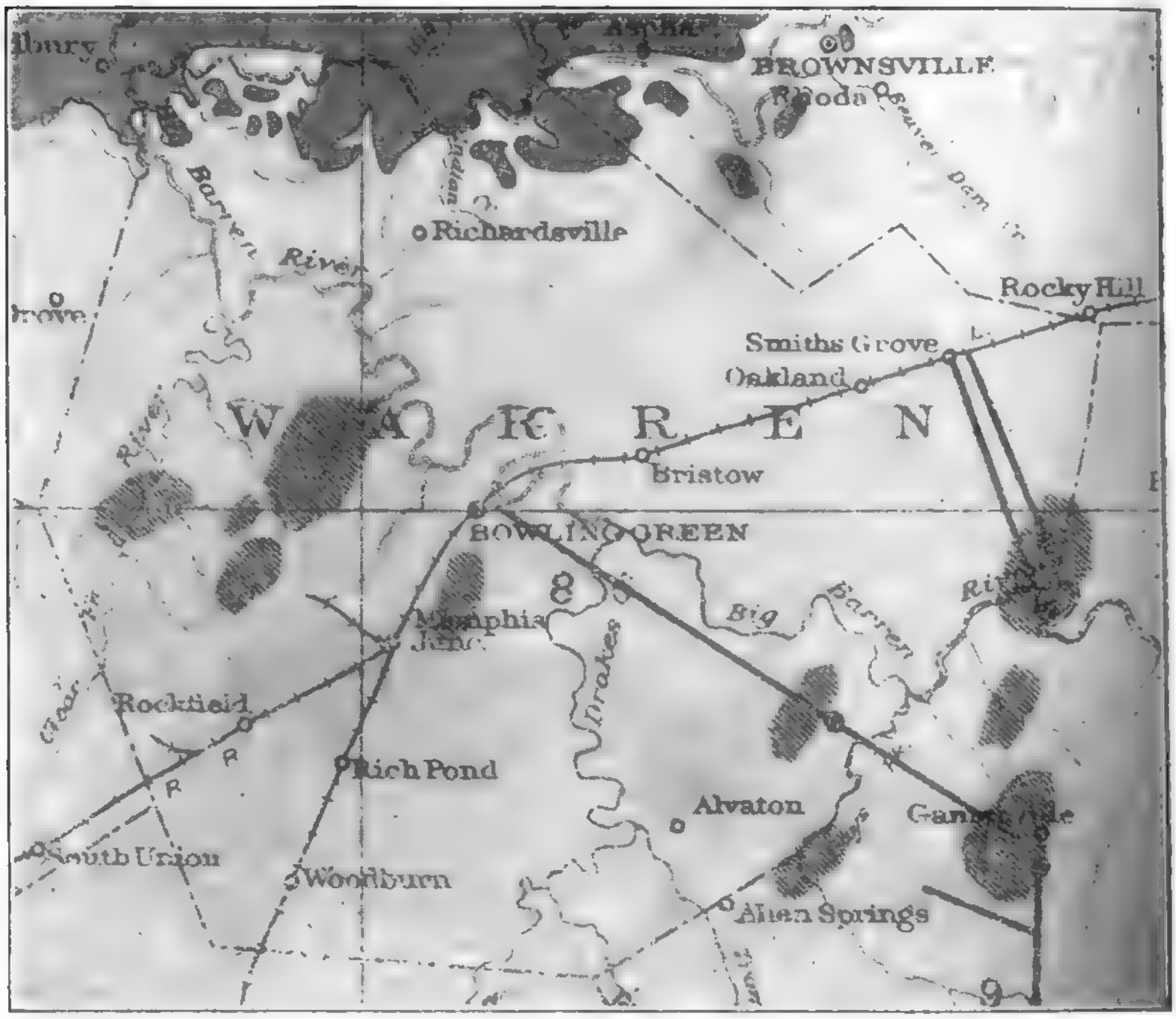
By Stuart St. Clair,
Assistant Geologist.

Introduction.

Prior to 1919 there were no producing oil wells in Warren County although there was considerable production in Allen County, the county adjoining on the east. A number of wells had been drilled in scattered localities from the eastern almost to the western edge of Warren County but the results had been unfavorable although some oil and gas had been found in the limestone underlying the Devonian black shale. The Jackson wells on Gasper River were probably the most notable of these early efforts and several wells were drilled, but the production was not of commercial size.

Naturally, oil development should start on the east side of the county nearest the producing fields of Allen County and scattered pools of Barren County. The Moulder pool, opened in the spring of 1919, furnished the first thrill. Wells of gusher type were brought in during this spring and summer from the top of the Corniferous limestone, which is subjacent to the Devonian black shale, at depths of little more than 400 feet. This started great activity in the area extending from Barren River north to Smiths Grove and west to the Three

*The Kentucky Geological Survey does not assume responsibility for any of the theories of oil migration from original sources which are advanced in this paper on Warren County.



OUTLINE MAP OF WARREN COUNTY.
The established oil pools and pipe lines of Warren County and the adjacent part of Allen County are shown.

Forks neighborhood. The early summer of 1919 saw many tests being made in other parts of eastern Warren County and a few small wells were struck just to the south of Rocky Springs school, about one mile west of Claypool, on the Williams, Motley, and adjoining farms.

A little later small wells on the Willoughby and Moody farms to the south were drilled in and also to the west in the Hardcastle area, on the Crow farm. Steady drilling has continued in the latter area ever since, although the wells are small. In the same summer a shallow well was drilled on the Covington farm on the Scottsville Pike near the Bowling Green city limits, oil of high grade coming from a "sand" at of depth of 355 feet. This discovery started drilling all around the city but nothing of commercial value was opened except

COLLEGE HEIGHTS PANORAMA.

The view is northwest and shows topography of the oil fields west of Bowling Green. The escarpment ridge can be seen in the distance and at its base are many good wells. The Little Briggs pool is in the foreground.

the small pool on the Thomas and Covington farms on the Smallhouse Pike, the production coming from probably the same shallow sand. No wells were developed in the sand below the Black Shale. Efforts in the southeastern part of the county near Drake post office were without commercial results. In the fall a small pool was opened up at Britts Mill, east of Claypool, in a sand probably equivalent to the Beaver, from which amber oil was produced, and also in the Corniferous sand below the shale. The discovery well in the Sledge pool in Allen County, near the Warren line, was drilled about this time.

On November 3, 1919, the discovery well on the Davenport farm, several miles northwest of Bowling Green on the Barren River Pike, was completed. The real development of Warren County dates from this time, although it was the spring and early summer of 1920 before the drilling campaign was in full swing. Deep wells have been drilled in the Davenport section and in a line south to the Dixie Highway with very encouraging results. In the early summer of 1920 a gusher was struck on the Tarrants farm, just east of the original Davenport, in a shallow and unknown "sand" at a depth of about 450 feet which added greatly to the boom already on. Wells in this shallow sand have been struck continuously in this section ever since. During the summer of 1920 additional shallow pools were opened in the McGinnis-Wilson area, west

BARREN RIVER TOPOGRAPHY.

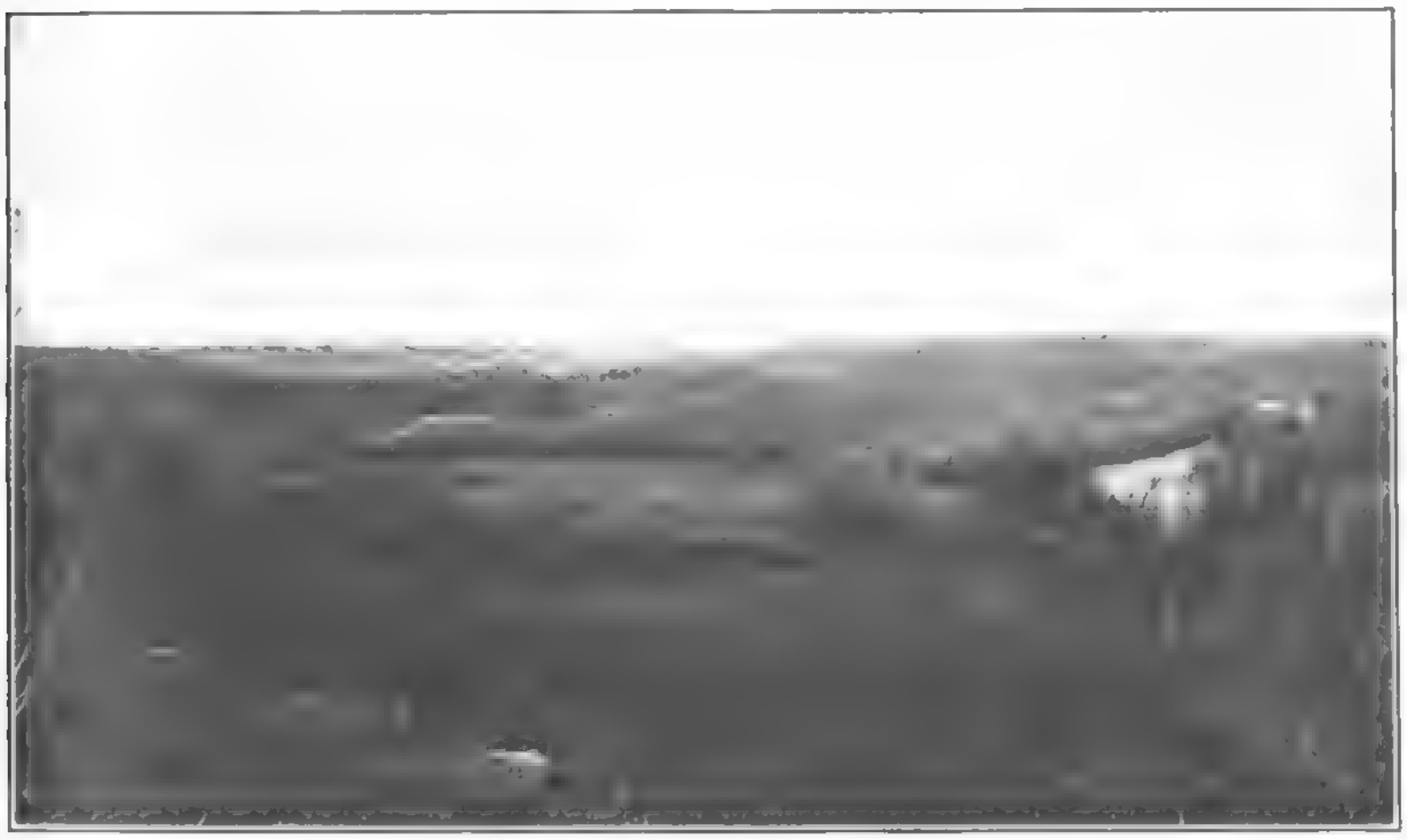
Looking North from Mt. Pisgah, Miller lease, Winlock Bend. Barren River is close on both sides of this hill. Views show Waller well and bend in Barren River, right center, the quarry ledge in the Gasper oolite, and cypress sandstone capping the ridge, 40 feet above quarry ledge.

of Lost River and a short distance north of Memphis Junction, and in the Roundtree-Covington-Bailey area east and southeast of Memphis Junction. In August the Whittaker shallow pool, just south of the Dixie Highway and about six miles southwest of Bowling Green, was opened with a gusher. Later other shallow wells were drilled in the vicinity and west toward Rockfield. It was also in August that the initial well at the western city limits of Bowling Green was completed on the Briggs lease and started a town lot drilling campaign. The latest shallow sand well of importance and which may open a new pool, was drilled in November, 1920, on the Jefferson lease on the Morgantown Pike where the pike crosses the first ridge west of Bowling Green. The deep sand drilling up to the end of 1920 had at least partly outlined the area of favorable sand condition and had shown several well-defined pools.

Topography.

Warren County may be divided into two topographic provinces, the larger being the plateau area which extends from

the east side of the county westward to the escarpment ridge, about four miles west of Bowling Green. This escarpment extends across the county in a general northeast-southwest direction and is a part of the series of ridges so plainly visible from the L. & N. R. R. from Elizabethtown to Russellville. The



A BARREN RIVER PANORAMA.

Looking west down Winlock Bend from Mt. Pisgah, Miller lease. Davenport Dome at lower end of bend. Escarpment ridge shown in distance.

plateau area is developed on the St. Louis and Ste. Genevieve limestones and is a rolling country deeply incised by the two main streams, Barren River which crosses the central part of the county in a general northwestward flow, and Drakes Creek, its principal tributary, which flows north through the east central part of the county. These streams have very meandering courses and have developed wide bottom-land areas in their many bends. The drainage of most of the remaining area of the plateau is underground, and the surface is marked by many sinkholes. The average elevation of the plateau is between 500 and 600 feet above sea-level.

The second topographic province is the highland area which occupies the northwestern part of the county and covers about one-third the area that the plateau country does. The high-

land area is developed chiefly on the Gasper limestone and Cypress sandstone and is from 200 to 250 feet above the plateau. It is deeply dissected by the drainage, Green River

A GOOD SHALLOW WELL.
Scott No. 1, White Oil Corporation. Flowing and pumping. On Scott Dome, Davenport Section.

on the northern edge of the county, and Barren River and its chief tributary, Gasper River, the latter flowing north along the west side of the county. The east side of the highland area is marked by the line of hills west of Bowling Green. The highest points are close to 800 feet and the lowest points along Barren River about 400 feet above sea-level. The country is very rough on account of the sudden relief from stream valley to hilltop.

Geology.

The geology of Warren County which we must consider extends from the Niagaran limestone of the Silurian to the Cypress sandstone of the Chester although the surficial geology is confined between the upper ledges of the Fort Payne of lower Mississippian age to the lower beds of the Pennsylvanian or Coal Measures.

Some deep tests for oil have penetrated the Ordovician limestone for probably as much as 600 feet or more in search of an equivalent of the Trenton oil formation of Ohio-Indiana. The well logs show prevailing limestones in the Ordovician and some oil is reported in the upper 100 feet of this series. The overlying Silurian, most of which is probably Niagaran, is made up chiefly of limestone with some shale and in places, probably near or at the base, a bed of red rock a few feet thick at the most which some drillers have reported oolitic and closely resembling the Clinton hematitic rock. Bailings from this horizon are red as blood. Some of these Silurian limestone beds are soft and earthy, and some are coarsely crystalline in texture. From well records the writer is inclined to put the thickness of these rocks at about 80 to 100 feet. Between these rocks and the Devonian black shale is about 50 to 55 feet of light gray to brown limestone which is probably Devonian in age and may be referred to the Corniferous limestone, the upper beds of which are the oil sands of northern Allen and eastern Warren counties. (The Corniferous is also the Irvine sand of eastern Kentucky.) At the outcrop of the Devonian limestone in Allen County its thickness is only a few feet, but evidently it thickens materially to the west. Most of the oil in the west half of Warren County is found at depths ranging from 68 to 135 feet below the Black Shale and, therefore, in the writer's opinion, comes from rocks of Silurian age.

The Devonian black shale, which is the key-rock for subsurface structural work, is about 50 feet thick in the eastern part of the county but thickens to about 100 feet in the western part with an average in the oil belt west of Bowling Green between 75 and 90 feet. The variation in thickness over short distances is due to an unconformity with the overlying Mississippian and, therefore, structural work should preferably be based on the lower contact of the shale, unless the thickness of the shale shows reasonable uniformity over the area to be mapped.

A DRILLERS' AND TOOLDRESSERS' CAMP.
Camp on Glen Lilly Pike west of Bowling Green and near Morris pool. These are oil field workers' homes.

The basal Mississippian formation in Warren County is the New Providence shale, which may be as much as 30 or 40 feet thick in the eastern part. At or near the top is a horizon probably the equivalent of the Beaver sand of Wayne County, Kentucky, a few wells of high grade oil have been struck. The oldest exposed formation in the county is the Fort Payne the upper ledges of which outcrop along Barren River in the extreme eastern part of the county. What is exposed here and in Allen County is largely chert, but presumably in unweathered or primary condition it is a silicious limestone for it is reported in well records as lime and sandy lime. This with the overlying Warsaw formation, which is chiefly fossiliferous limestone with some shale, the latter usually at the top, are about 220 feet thick in eastern Warren County, but these two formations must thicken, probably largely the Fort Payne, in going westward, for in the deep pool area west of Bowling Green, from a study of well logs, there is an interval of 330 to 340 feet from what is probably the basal part of the St. Louis to the top of the Black Shale. This would include the New Providence, if present.

The St. Louis limestone is the next younger formation and may be unconformable with the underlying Warsaw, a relation that is suggested by absence of the Spergen limestone and cross-bedding and coarse-grained layers in the basal part of the formation. The St. Louis is a dense blue to gray limestone evidently very silicious in many horizons as weathering produces large quantities of chert. The formation can be recognized by the coral Lithostrotion basaltiforme which is scattered over the surface as chert pieces and which is diagnostic of the St. Louis. The plateau area and sink-hole topography of the county are developed on the St. Louis and overlying Ste. Genevieve formations. There is some question from what formation the gusher shallow wells of Warren County come, but it is the opinion of the writer that the lower or even basal limestone beds of the St. Louis are the oil sand. A fragment of Lithostrotion basaltiforme was recognized in a piece of rock shot from one shallow well,[1] and the writer was given two pieces of water-worn fragments of chert

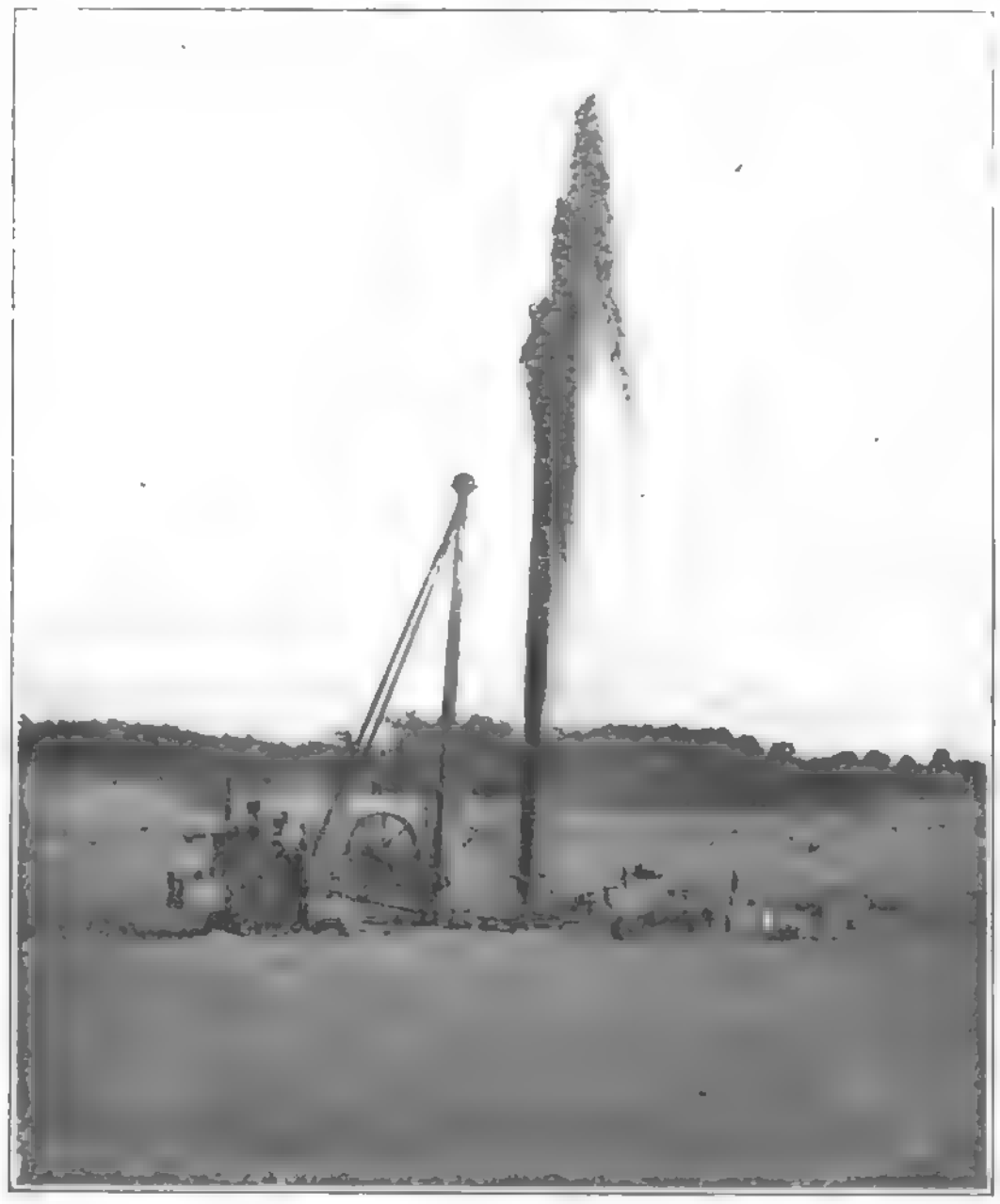
OIL DEVELOPMENT IN BOWLING GREEN.
Little Briggs oil pool at west edge of Bowling Green. View looking east from tank house on Briggs lease.

[1] Written communication from Wilbur Nelson, State Geologist of Tennessee.

which were drilled from two wells in widely separated localities. From drill records the writer puts the thickness of the St. Louis, considering the oil horizon to be basal, at 335 to 350 feet.

The Ste. Genevieve, which includes the Fredonia member, and the Gasper may be considered together for lithologically they are hard to separate as both are light colored limestones, and both are oolitic. The general absence of chert and Lithostrotion basaltiforme identifies them from the St. Louis. No unconformity was found at the base of the Ste. Genevieve in Warren County, but a basal conglomerate does exist at a few places far removed from this area. The absence in Warren County of the O'Hara member of the Ste. Genevieve and the Bethel sandstone, which appears in Todd County to the southwest, may or may not denote a stratigraphic break at the base of the Gasper. From a study of well logs the thickness of the Gasper and Ste. Genevieve must be between 390 and 400 feet. This seems excessive and the writer can offer no data to explain this thickness.

The Cypress sandstone overlies the Gasper. The basal bed exposed along the escarpment ridge four miles west of Bowling Green is a yellow to gray shale from five to seven feet thick above which is cross-bedded sandstone. There may be an unconformity at the base of the Cypress as the depths of some wells not far apart from the top of the Gasper to the top of the Black Shale show considerable differences, but it must be borne in mind that there are other breaks in the stratigraphic column which might account for these differences. A few records along the escarpment ridge are given to show this relation. At the gap on the Morgantown Pike, Jefferson lease, the calculated interval from the base of the Cypress to the top of the Black Shale is about 1,086 feet. On Salt Lick Creek one mile to the northwest the interval is about 1,073 feet. On the ridge less than a half mile north of the Morgantown Pike the interval is about 1,066 feet. At the Brownfield wells, southwest of the Davenport, the interval from two wells is 1,085 feet. On the Barren River Pike west



SHOOTING MOYER No. 1.
This well is located on the Glen Lilly Pike 3 miles west of Bowling Green.

of the Davenport the logs of two wells a half mile apart show the interval to be 1,091 and 1,092 feet.

In the northwestern corner of the county a few thin Chester formations above the Cypress come in, above which lies unconformably the Pennsylvania sandstone and conglomerate.

Structure.

The general structure of Warren County is a north-westward dipping monocline, the average dip being 30 to 40 feet to the mile. This regularity is broken by several uplift areas which extend in a general direction normal to the monoclinal dip. These cause reversals of dip to the southeast and increases the northwest dip in many localities. There are also a few low folds which parallel the northwest dip of the rocks and produce domes and terraces.

There is evidently an uplift extending northeast-southwest along part of the eastern side of the county for along Bays Fork and Barren River there is a series of domes, the domes occupying many of the bends in the streams mentioned, the more prominent being at Cornwall Ford, Sledge pool, Britts Mill, Evans Bend, Jewell Bend, and Moulder pool. Drakes Creek follows another line of uplift as many of the bends are structural. West of Bowling Green is probably the most discernible series of folds in the county, the uplift paralleling the escarpment ridge. How far it extends to the northeast and to the southwest the writer has not determined, but there is no reason why it should not extend across the county. Smaller paralleling folds lie a little southeast of the major fold which is at the base of the range of hills. On the western side of the county Gasper River in part follows an uplift for well-defined domes occupy many of the river bends. Between the escarpment ridge to the east and Gasper River, the area has a very uniform monoclinal dip which is broken by terracing in a few localities.

An area of uplift extending from Bays Fork to Hardcastle paralleling Barren River is suggested by the series of small wells included in the Claypool, Green Hill, and Hardcastle districts. The large area north of Barren River and east of the escarpment ridge has, probably, a uniform dip as no structural irregularities of prominence were observed. The same may be said of the area in the southern part of the county lying between Drakes Creek and the Memphis Branch of the L. & N. R. R. An interesting feature in the geology is the relation of the structure to the main drainage and to the topography in the western part of the county. Nearly all of the prominent bends in Barren River and its three main tributaries are structural. The domes and terraces in the highland area are strongly reflected in the topography.

Occurrence of the Oil.

Oil has been found at eight or nine different horizons in the geologic section that has been drilled through in Warren County, six having proven commercial. For brevity the six

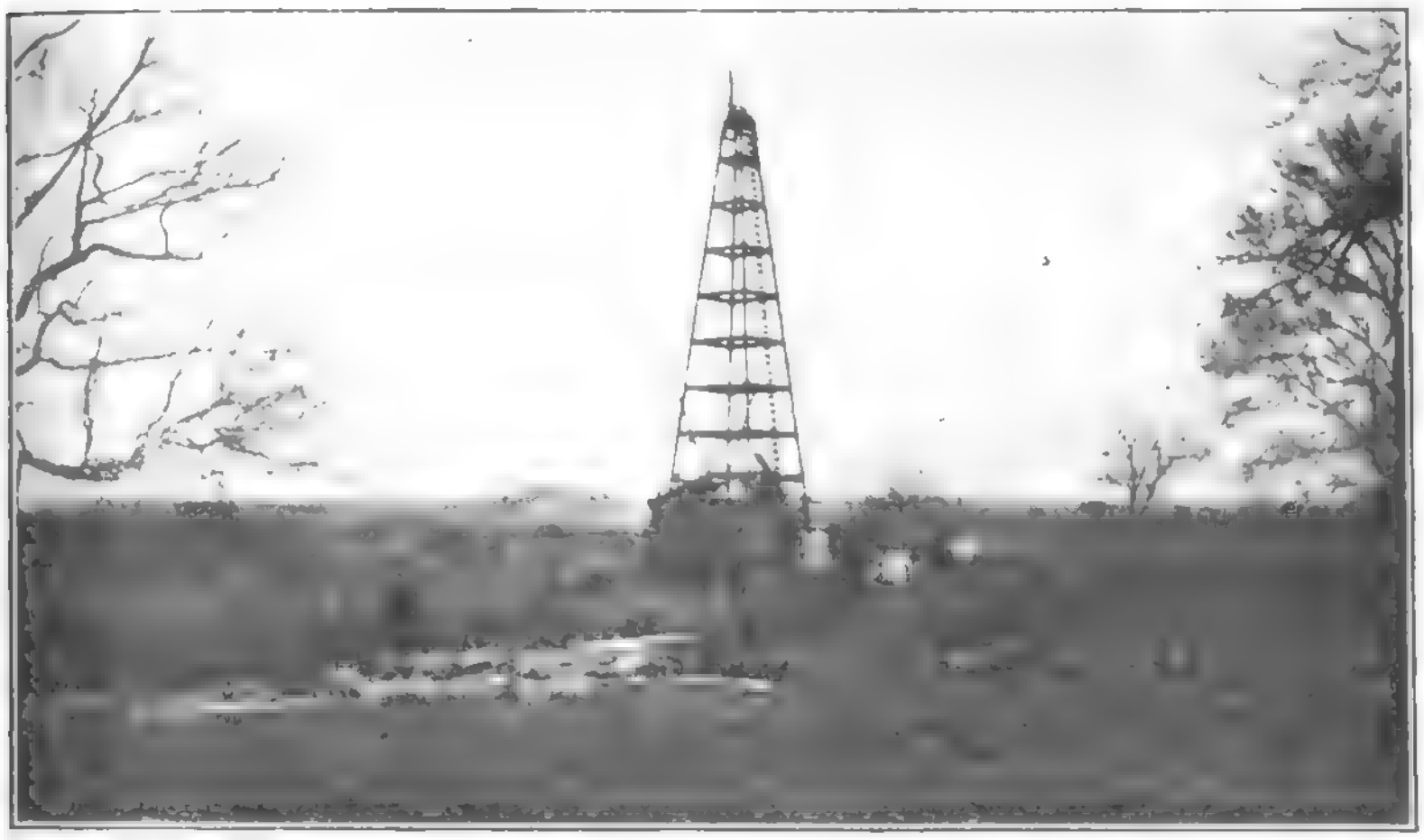
may be grouped into four so as to make formational units. These oil sands are the basal St. Louis in which the gusher wells in the Bowling Green area are found; the Beaver sand which occurs in the New Providence above the Black Shale in the eastern part of the county and from which the amber oil is produced; the Devonian lime sand with its two pays, the first a few feet below the Black Shale, the second about 45 feet below, the Devonian being the big producer in the eastern part of the county; and the Silurian, probably all Niagaran. lime sand with its oil horizons at 68 to 130 feet below the Black Shale, and being the consistent deep producer west of Bowling Green. A detailed description of the commercial sands is given below.

JOHNSON No. 1 SHOT.
Shooting Johnson No. 1. This well is located in the Davenport section.

St. Louis sand. The sand which produces the gusher wells of the Bowling Green district is thought by the writer to be at or near the base of the St. Louis limestone, the oil probably

coming from the lower 20 or 30 feet. The lower beds of this formation can be studied at their outcrop in the eastern part of the county as well as in Allen County. They lie immediately upon a persistent and easily recognized calcareous shale bed about 20 feet thick of the Warsaw formation and are in many places cross-bedded and coarse-grained in texture. In the eastern pools of the county, the basal St. Louis is about 250 feet above the top of the Devonian black shale. In the Bailey shallow oil pool five miles south from Bowling Green along the L. & N. R. R., the shallow oil is between 325 and 335 feet above the Black Shale. These wells start in the Ste. Genevieve oolitic limestone just above the top of the St. Louis cherty limestone. The shallow oil is found at depths from 340 to 360 feet. Farther northwest, or down the dip, in the Davenport section the interval between the shallow oil and the top of the Black Shale is 340 to 350 feet. This shows a thickening of the Mississippian formations below the St. Louis in going northwest toward the Central Coal Basin of western Kentucky. The St. Louis sand is a dark granular and well crystallized limestone. When drilled up it looks like dark carbonaceous sand but when larger fragments are bailed out it is seen to be crystalline and to contain many fragmentary fossil shells and is soft enough to be crushed between the fingers. Most of it will dissolve in acid and any residue is chiefly amorphous silica. This dark limestone may have a considerable thickness in some localities and intercalated with it are thin black to brown shale lenses. Fragments of fossils are abundant and in two localities pieces of water-worn chert, which the writer saw, were said to come from the oil sand.

The basal St. Louis oil sand is not persistent laterally for offsets to good wells may not find any oil and in many cases no water either. The writer suggests, therefore, that the basal beds where productive may occupy shallow erosional depressions in the underlying formation, or sink holes, which may have formed in the soluble Warsaw limestone during the interformational epoch, and that the black shale lenses may be confined to areas where these depressions existed at the time



THE OCCASIONAL STANDARD RIG.

This standard rig on Davenport 3 miles west of Bowling Green on Barren River Pike is the exception rather than the rule in the Warren County Fields. The topography of the Plateau area in this oil field is well shown in this view.

of basal St. Louis deposition. Satisfactory records are not available nor was the writer able to examine the cuttings from enough wells to verify the presence or absence of these thin shale beds in the wells which produced or did not produce oil from this sand. The presence of soft carbonaceous limestone, and in many wells studied carbonaceous black shale, coarsely crystalline limestone, abundant fossil fragments, probable water-worn chert fragments, and irregularity in areal distribution of the oil horizon, suggest basal sedimentation.

The St. Louis sand contains gas, oil, and salt water all of which are under great pressure in the big producing wells. The pressure is soon relieved, however, and the decline in production is very rapid, especially after several wells are drilled in the same locality. Seibert No. 1 at a depth of 423 feet is claimed to have flowed 2,500 barrels of oil the first 24 hours. Whittaker No. 1 which burned for several days after blowing in at a depth of 479 feet is said to have produced 1,500 barrels the first day after the fire was extinguished. This was on August 14 and on November 30, 1920, was still pumping 50

barrels per day. Whittaker No. 5 at 473 feet gauged 1,400 barrels the first 24 hours and after seven weeks was pumping 50 barrels per day. Tarrants No. 1 at 453 feet, the first big St. Louis well to be drilled in Warren County, completed early in May, 1920, produced over $50,000.00 worth of high grade oil in the first few months, and No. 3, same lease, has produced even more than this, but over a longer period. Many wells from 400 to 450 feet in the Davenport section have produced initially from 100 to 500 barrels and are now pumping, December 31, 1920, from 10 to 25 barrels at ages from three to six months. These are illustrations of a few wells that have held up better than the average. Some wells have come in flowing salt water, others have pumped salt water for a few hours or days and come on to oil. Each pool or unit in a pool has just so much fluid in it, evidently, and a well pumping salt water from a location down the dip from a producing oil well may draw the oil from the producing well, the former changing from water to oil. Shooting a well may ruin an offsetting producer, and in other cases dry holes may be drilled surrounding a producer. These facts show the spotted distribution of the St. Louis oil sand.

The oil and gas are probably indigenous to the basal beds of the St. Louis and come from the carbonaceous shale and the organisms, the fossil remains of which we now find in the limestone. The salt water is fossil sea water and is confined to the depression areas in which the basal oil horizon was deposited. The oil and gas have not migrated far from the points of origin and have arranged themselves, as far as pent up gas pressure would allow, according to their respective specific gravities in the small pools or units of a larger pool.

The accumulation of oil into pools in the St. Louis sand is only indirectly controlled by the structure of the rocks as the determining factor is the presence or absence of the basal oil horizon and this is dependent upon the sedimentary conditions that obtained at the beginning of St. Louis time. Where the basal oil horizon underlies a considerable area, structure has an influence on the accumulation and pools may coincide with

TYPE OF PORTABLE RIG.
Drilling on the Mercer lease, National Exploration Company, 4 miles west of Bowling Green. Shows 28 Star Steam drilling rig.

the top of a dome or its flank. However, on many of the most pronounced structures in Warren County the basal St. Louis oil sand is absent.

The largest area or pool of the St. Louis oil is in the Davenport section, between three and four miles northwest of Bowling Green. This area lies along Barren River Pike and in the Seibert and Winlock bends of Barren River. Although many wells are scattered over a large area and there may be a number of wells in a given locality, yet there is much of the territory over which no oil was found in the basal St. Louis beds. For example, one well near the top of the Davenport dome at Thomas Landing is surrounded by wells which produce from the deeper sand but in which no oil was found in the St. Louis sand. Several producing wells in a group, probably low structurally, may have a dry hole in their midst in which the St. Louis sand was absent.

ON THE McGINNIS LEASE.

McGinnis No. 2, Morris Dome. View looking West toward escarpment ridge which is the west flank of the dome. Cedars in foreground are near the top of the dome.

The McGinnis pool, between the Franklin Pike and the railroad at Lost River three miles south of Bowling Green, is located on a well-defined dome, as shown by subsurface studies. A little farther south along the Franklin Pike east of Memphis Junction and extending eastward to the Smallhouse Pike a number of St. Louis wells were drilled with large initial productions, but they declined very rapidly. The Bailey pool

farther south on the same pike was of similar character. Some wells were drilled east from this area in the vicinity of Plano but the writer was unable to make an investigation of this area. It may be assumed, however, that they are of similar character to the Bailey and other close by pools.

The Whittaker pool, which produced some of the largest of the St. Louis wells, is along the Memphis Branch of the L. & N. about midway between Rockfield and Memphis Junction. The pool lies on the flank of a small anticline and is of very limited extent as wells offsetting some of the big producers were dry. A probable extension of this pool lies along a small fold to the southwest toward Rockfield. There are a few shallow wells at the western city limits of Bowling Green interspaced with the deeper wells, and a few scattered ones southeast of the city one of which, the Covington, was the first St. Louis sand well discovered. A well drilled on the Jefferson lease where the Morgantown Pike cuts across the escarpment ridge four miles west of Bowling Green the latter part of November, 1920, and which started at 200 barrels per day may open up another St. Louis sand pool. Its extent, however, will be limited as wells on two sides failed to find this horizon productive.

There seems to be little chance for controversy regarding the origin and accumulation of the oil in the St. Louis sand. The character of the sediments and the localization of the pools point to the origin of the oil being from and the accumulation in the sediments of the basal St. Louis limestone, as there is no connection between the lower oil sands by faulting or fissuring, as far as can be determined by surface observation.

Beaver "sand." The Beaver sand is productive only in the eastern part of the county and is found at the top of the New Providence formation in a lime sand. The oil is very high grade and amber in color and is probably a product from the organic matter which was deposited with the underlying green colored shales. Accumulation is dependent entirely upon the presence or absence of the sand, which is lenticular, and secondarily upon the structure. Some of the wells come in at

100 barrels or better but they soon decline to small production. The only wells producing from this sand at the present time, known to the writer, are in the Sledge pool and at Britts Mill, both on Bays Fork.

Devonian "sand." (*Cornifcrous*) The Devonian lime sand which underlies the Black Shale is productive principally in the eastern part of the county. There are two pays in the pools of this section and both are thought to be in the Devonian, although the lower may be in the upper ledges of the Silurian limestone. The first pay is the important producer and lies from a few feet to about ten feet below the base of the Black Shale and is from five to ten feet thick. At the present time all the wells in this sand have small production although the first wells in the Sledge and Moulder pools blew in at from 100 to 1,000 barrels. The Moulder wells declined rapidly but the first few wells in the Sledge pool, by pinching them in, held up for some months and produced a great quantity of oil. The pay sand in these pools is brown in color and very porous. The oil was under both gas and salt water pressure, and as the pressure is now relieved the wells are nearly exhausted. There is scattered production along Bays Fork from the Cornwall lease to Britts Mill, the accumulation being on a series of domes. There are a few small wells near Barren River, at Three Forks, and in the Moulder District but the writer has not worked out all of their structural relations as they do not constitute a group of any importance. The Moulder wells which produced so large at the start are located upon a low dome.

The section extending from the Willoughby wells near Bays Fork northwestward to Hardcastle, and taking in the wells of the Williams-Motley, Green Hill, and Hardcastle areas, contains many small wells many of which are on the pump. Sand conditions are not very good, the rock being close-grained, and there appears to be no free circulation of the oil and little if any salt water in the oil formation. The smallness of the wells is probably due largely to the non-porous character of the rock. The writer has made no study of the

A DAVENPORT POOL WELL.

Completion of shallow well in St. Louis sand on Davenport lease, Big Jack Oil Co. on bank of Barren River. It flowed over top of the mast. Depth between 400 and 450 feet. Type of drilling rig used.

structural occurrence of the oil in this section but it is his opinion that structure would exert but a small influence in the accumulation of the oil. On the north side of Barren River on the Gott lease there are a few small wells which probably get the oil in the lower part of the Devonian limestone. The wells are located on the north flank of a dome but the accumulation is probably due largely to an area of local porosity in the rock. Some salt water is also found here lower in the Silurian rocks.

As far as the writer knows there is but one commercial well in the field west of Bowling Green that is producing from

the Devonian. This well was brought in the middle of December, 1920, and is producing from a ten foot pay which is 36 feet below the base of the Black Shale. The structure is a terrace on the monocline northwest of the escarpment ridge. Many other wells producing from the Niagaran sand have reported a showing of oil at this horizon.

In Simpson County just south of the Warren line and on the Franklin Pike, the Mitchell wells are in the Devonian about 25 feet below the base of the Black Shale.

Silurian "sand." (*Niagaran*). The Niagaran sands are the present big producers in Warren County. The second pay in some of the wells in the eastern part of the county may be in the Niagaran and the pay in the Beatty District two miles west of Three Forks on the Porter Pike is in the Niagaran limestone 90 feet below the Black Shale. In the western part of the county the pay may be 68 to 130 feet below the Black Shale, two pays probably being represented in this interval but they will be discussed together. The color of the pay sand is light or dark gray and the rock is soft and either earthy in appearance or crystalline, and contains very little grit.

The Niagaran limestone is apparently non-productive over the larger part of Warren County. The three-fourths of the county lying east of the Richardsville Pike, which runs north from Bowling Green, and south and east of the Russellville Pike, which runs southwest from Bowling Green, has been scatteredly drilled and although showings of oil have been found in many wells, the rock has generally been tight and dry. Within the area included in the boundaries given, occupying the western part of the county, the extreme eastern part is underlain by good sand conditions. The western and northern parts are largely unproven although a number of wells were drilled which showed unfavorable sand conditions for oil accumulation in commercial quantities. The real area of production is small. Taking the western edge of Bowling Green as the apex the producing area extends out fan-shaped covering an arc of about 125 degrees. The limit of the fan is but

a short distance beyond the escarpment ridge, approximately four miles from the apex, but it may be extended a little farther. Within this fan area of production there are a number of non-productive sections where either the rock structure is too low or the sand condition is poor. Most of the producing wells are located on the tops and along the flanks of the anticlines and domes. In the saddles and in the synclines the sand condition is generally poor, and little if any oil is found and rarely salt water to amount to anything.

THE SPECTACULAR TARRANTS LEASE.

Tarrants No. 1, first shallow St. Louis sand well west of Bowling Green. This well produced over $50,000.00 in oil in the first few months. Depth of well is 453 feet.

The most pronounced line of structures, and upon which some of the best wells in the district are located, extends along the base of the escarpment ridge from the Morgantown Pike to the north side of Barren River.[2] The Niagaran sand is uniformly porous under this anticline which includes the Briggs dome, just north of the Morgantown Pike; the Morris dome, just north of the Glen Lilly Pike; the Scott dome; and the Davenport dome, at Thomas Landing on Barren River

[2]This anticline was first mentioned by Shaw & Mather in Bulletin 688, page 114, of the U. S. Geological Survey several years before it was drilled.

Pike; and across the river the domes in Winlock Bend. Distinct saddles separate each of these domes. Paralleling this anticline and lying to the east of it are other anticlines, on one of which the Little Briggs pool at the city limits is located.

The Davenport dome, which has been drilled extensively and on which the writer has accurate records, has a 40 foot closure. The surface elevation near the river at well No. 15 is 444 feet above sea-level, and the depth to the top of the sand is 960 feet, bottom 967, and the base of the oil is, therefore, 523 feet below sea-level. The pay is from six to 20 feet thick in this section and very little salt water is found in the oil formation. This water is under no pressure and is evidently not bottom water but occurs directly in the pay. Adjoining wells may show no water at all. These features will be discussed fully under origin.

The top of the Niagaran sand in the wells west of Bowling Green is between 68 and 115 feet below the base of the Black Shale. This range undoubtedly covers more than one horizon, although the color and texture of the pays are quite similar. In the Little Briggs pool at the western outskirts of Bowling Green the pay is usually found at 80 to 90 feet below the Black Shale but in a few wells where this sand was missed oil was found at 183 feet under the Shale. The pool is on a plunging anticline and many of the wells are of small capacity although a few are much larger than the average size well of the county. One well six months old is said to be pumping 40 to 50 barrels. The average depth is under 900 feet but in a few wells where drilling has gone to the deeper pay the depth is nearly 1,000 feet. Farther west in the Davenport section the wells vary in depth from about 950 feet in the vicinity of the river, where the surface elevation is close to 450 feet above sea-level, to 1,100 feet in the valleys leading to the river and in which the surface is not rugged. There is a progressive deepening in going westward, and on top of the escarpment ridge the depths of wells are 1,300 feet and over.

On the Davenport dome, the top of which is at Thomas Landing on Barren River, the top of the pay sand on the Big Jack lease is 85 to 90 feet below the shale. To the west on the flank of the dome the top of the pay in Johnson No. 1 is 89 feet below the shale and in No. 3, 500 feet distant, the top is only 74 feet below the shale. Riggs Davenport No. 1 in Winlock Bend has pay at 75 feet under and on east at the Waller well the pay is 80 feet under the Shale. In the Morris pool, end of the Glen Lilly Pike, the top of the pay varies considerably. Morris No. 1 has a small pay at 40 feet under which is Devonian, but the best pay is at 68 feet under the Shale. In No. 3, two locations distant, the top of the pay is 82 feet under and one location farther 83 feet under. In the Briggs pool, on the Morgantown Pike, the pay is 112 to 115 feet below the Shale. These few figures will give a general idea of the variation in the position of the pay sand over very short distances. The thickness of the pay likewise varies over short distances, it varying between four and 21 feet.

Salt water was encountered in a few wells in the producing territory but the amount is negligible and may not be found in offset wells. Its occurrence may be in wells located high upon a dome and yet it may be entirely absent in wells lower on the same structure. It is, therefore, in pockets and not in a regular salt sand. In Rays Valley, outside of the present producing area, one well is pumping considerable salt water at 117 feet below the Shale and another encountered a larger quantity at 135 feet below. However, there are enough tests around the present producing area to indicate that there is no quantity of salt water behind the oil.

Source of the Oil.

A full discussion of the source of the oil in the Devonian and Silurian sands is not pertinent to this brief resume of the oil pools in Warren County, therefore this point will be only briefly considered.

The oil is either indigenous to the Devonian and Silurian limestones and probably to the sand horizons themselves, or the oil has migrated from the overlying Devonian black shales

to the sands below. The presence of a porous bed in the limestone is the all important factor in the accumulation of the oil although other factors may offset the presence of this requisite. Therefore, drilling may disclose a porous bed in the limestone which may or may not contain oil. On the other hand wells may be drilled on good structures and no oil or salt water found because the rock is tight although fossils, which are evidence of pre-existent organic life, are found in what should be the oil pay, or adjacent to it. Again, wells drilled on favorable structures may find amply porous rock but be barren of oil or water. Salt water is found in quantity in the pools of Allen County and in the eastern side of Warren County but little or no salt water is found in the Devonian or Silurian sands in other parts of the county.

FIRST WELL IN DAVENPORT POOL.

Davenport No. 1 discovery well of the oil fields west of Bowling Green, and C. G. Davenport himself, royalty owner and father of the Davenport oil district. Ridge in the distance is the Northwest flank of the dome.

The presence of porosity in the limestone is due to different causes. The extreme eastern part of Warren County and much of Allen County are in an area where the porosity of the limestone is due to the solvent action of meteoric water which has entered at the outcrop of the limestone and has

slowly percolated through the rock, dissolving the more soluble parts of the limestone and the saline residue on its travels down the dip of the strata. The distance from the outcrop to which this action has been effective is a function of the length of time the outcrop of these beds has been exposed to meteoric water. At the limit of the altered area there must be a large accumulation of water which is dammed back by the tight limestone which is yet unaffected by the meteoric water.[3] The writer has regarded for a long time the extreme eastern side of Warren County to be close to the line of separation of the porous area, produced by meteoric water solution, and the nonporous area, and that the water trough must lie along this line. The occurrence of the oil and the great pressure behind it in the Moulder, Sledge, and adjoining areas showed this to be the true condition, and although considerable oil was recovered, the pools declined very rapidly and salt water in small or large quantities, depending upon how much of the original pressure had been relieved, replaced the oil. The oil has evidently migrated from the fine-grained black shales to the underlying porous limestone through channels provided by joint planes and probably through incipient fissures which must be developed in rigid rock in folded areas such as are found in Allen and Warren counties.

The Green Hill-Hardcastle area is out of the zone in which meteoric water has produced porosity in the limestone. Therefore, it is suggested that the porosity may be primary or due to recrystallization or partial dolomitization. Since all of the wells are small with no pressure back of the oil, and with many tight-sand wells all around, the porosity of the rock must be small and the accumulation erratic. Samples of the sand, results of drilling, and performance of the wells check these conclusions closely.

In the producing area west of Bowling Green the Niagaran limestone appears to have ample porosity at the oil horizons

---

[3] The writer has given a more detailed description of this origin of porosity in his paper on the "Irvine Oil District, Kentucky" Dept. of Geology & Forestry, Resources of Kentucky, Series V, Vol. 1, No. 2, July, 1919; and Bulletin 151, July, 1919, American Institute of Mining Engineers.

to allow large accumulations. The writer has no evidence at the present time that the porosity is the result of secondary processes. On account of the earthy texture of much of the producing sand the porosity may be due to primary depositional conditions, although the crystallinity of some of the oil sand suggests secondary action. If the sand porosity is the result of favorable depositional conditions during this stage of Silurian sedimentation, either these special conditions were very local, for to the south, the east, the north, and a few miles west (the western limit of the field is not yet fully determined) the Silurian limestone does not contain oil in commercial quantities, or the absence of oil in the same limestone, which underlies the barren area surrounding the producing field, is due to some condition which has prevented migration from the overlying Black Shale, provided the source of the oil is the Black Shale. Many wells barren of oil or salt water have gone through porous beds in the Niagaran limestone. There was probably ample fauna in the limestone from which the oil could originate, and if the limestone is the source of the oil there appears to be no reason why the pools are not more generally distributed throughout the county and region. Also, since there is no hydraulic pressure in the oil horizons if the oil was formed within the limestone there is no possibility of migration and therefore no reason for accumulation on the higher structural points. Yet the best wells in the Niagaran sands conform closely to the structures. As noted before, wells on the structures usually find good sand conditions; many wells close by in the saddle and synclines have poor sand conditions generally. May there not, therefore, be some peculiar relation between structure and sand condition and localization of oil accumulation? The writer wishes to express the following thought as a possible explanation of the origin and accumulation of the oil in the sands underlying and within a reasonable depth beneath the Black Shale.

The folding which parallels roughly the escarpment ridge, the division between the plateau and the highland areas, was probably more acute than in any other part of this general

district and produced a series of paralleling domes with interdomal saddles and synclines. The folding is less intense as the distance increases from the escarpment ridge. Jointing in the rocks show a general northeast-southwest and lesser northwest-southeast direction, a phenomenon which shows the axes of stress and strain. This pronounced folding very probably produced similar jointing and probably some fissuring of the hard limestone beds which underlie the Black Shale. Through such channels there would be a direct connection between the petroliferous black shales and water-saturated limestone beds below. (The less dense limestones are evidently saturated for shooting frequently brings in some salt water which can be quickly pumped out. There is, however, no hydraulic pressure behind the water.) The oil would pass from the denser and finer grained shale to the more porous water-saturated limestone bed on account of the difference in the capillary pressures of oil and water (a phenomenon of surface tension). The interchange would progress to the point where equilibrium was established, at which time no further migration of the oil could take place either downward or a return upward. Deposition from the ascending water might close many of the channels of migration even before equilibrium was established. Naturally there were some beds in the limestone which were more porous than others and, therefore, contained more water, and to these more porous beds the oil would have the greater tendency to migrate. The oil may have had some chemical effect upon the sand and given it the earthy texture which can be recognized in the cuttings from many wells. So the porosity and general appearance of the oil sand may not be due entirely to depositional conditions but may be, more or less, due to secondary action from the oil content.

The areas of jointing and even fissuring would be most pronounced where the folding was the severest. These areas would, therefore, coincide with the domes and anticlines, and the saddles and synclines would be affected to a much less extent, and probably in many cases not at all. Therefore, the

migration of the oil from the Black Shale to the sand would take place primarily on the structures and to a lesser extent on the flanks or in the saddles or synclines. Likewise, there would be less chance for accumulation of oil in paying quantities the farther away from the line of major structural disturbance, which apparently was near the foot of the escarpment ridge, because of a decrease in the amount of jointing and fissuring. The oil primarily accumulating on the structures would remain there for the water in the saturated porous beds would prevent the oil moving down the dip by gravity.

Some wells were drilled on promising-looking structures and porous rock was found at the horizon which is producing at no great distance away. The absence of oil in these wells may be due to a lack of fissuring or jointing which extended from the shale to the sand. In other words, the area did not receive enough stress during the formation of the fold to create the requisite jointing or fissuring. Many other wells drilled on good structures have failed to find any porous beds in the limestone underlying the Black Shale. The absence of either the channels for migration or a porous, water-saturated bed would prevent accumulation in commercial quantities.

Although the above thoughts are in the rough and may need amplification, it may be readily seen that the following facts can be explained by this theory. Localization of the producing area: presence of the oil on domes and anticlines without water pressure behind it (a modification of the present general interpretation of the anticlinal theory); absence of oil in favorable structures which are underlain by porous strata below the Black Shale; absence of oil under so large a part of Warren County but under which the same fossiliferous Devonian and Silurian limestones and petroliferous black shale extend. It would be hard to explain any of these four primary facts by the theory that postulates that the oil is indigenous to the limestone in which the accumulation has taken place, although there are some arguments which can be advanced in its favor.

In a few places a little oil has been found in a sand lower than the Niagaran. The writer has no detailed records of the performances of these wells except that the well on the Thomas Covington lease south of Bowling Green at 250 feet below the Black Shale was said to have pumped five barrels per day for a while. The sand is very probably in the upper part of the Ordovician. A few wells in the Little Briggs pool just west of Bowling Green have found some oil probably in the Ordovician at 183 feet below the Black Shale.

Extension of the Field.

The object of any geologic study of an oil field is to determine such facts that will be of value in extending the area of production and minimizing the expense of doing so: in increasing the production of the wells; and in conserving the resources of the field by preventing waste of the oil produced and waste of money, time, and energy in the development of the field. From such a preliminary study as the writer has made probably the only valuable objective reached, aside from acquainting the public with the general geologic and economic conditions of the field, is the framing of some theory which may point out the areas which should be tested in an endeavor to extend the field and to call attention to the much larger area which should be but sparsely drilled. With no definite views on the probable origin and accumulation of the oil many geologists would recommend the drilling of all domes and terraces for these structures prevail where the oil pools are located. But many similar structures have been drilled without success and there must be reasons for such results.

Accepting, if you will, the theory of origin and accumulation as outlined by the writer, an endeavor to extend production should be along the line of intensest folding which is probably close to the escarpment ridge, and domes should be selected along this line for initial tests. The writer has not traced this line of folding to the northeast and only for a short distance to the southwest, but it seems reasonable to believe that the folding should extend for some distance both ways from the Bowling Green field. But how far favorable

sand conditions extend from the producing area cannot be told except by drilling. If a working theory of the origin of the porosity in the Niagaran limestone could be advanced, a prediction as to the extension or limits of the field might be made, as was done in the "Irvine Oil District, Kentucky."[4]

The above remarks on the probable extension of the field west of Bowling Green applies only to the sands which underlie the Black Shale, namely the Silurian. The St. Louis oil horizon is different and the possibilities of finding new pools in this sand were outlined earlier in this report.

Economic Considerations.

Should some writer give a good general description of economic conditions in an oil boom community, it would only be necessary to change names in order to apply the stereotype form to all boom localities for practically the same basic conditions prevail, exaggeration and inflation. Warren County has passed through such a period, the peak of inflation having passed in the late summer and early fall of 1920. Very few who bought on the wave of inflation will make any profit from their investments and many will not even get their money back.

The Moulder pool started inflation in that part of the county and in adjoining counties and only those who passed their purchases on to others while the boom was yet on made anything from their investments. A similar condition obtained in the Sledge district, although more oil was run through the pipe line and the early comers who drilled and got production were successful, more or less. The buyers of the much larger area which was purchased at inflated prices and which has proven barren of oil can only write off their losses, and some of the purchasers of production must realize that they hold the sack. No such inflation was reached in other parts of eastern Warren County although leases changed hands many times at prices infinitely greater than their intrinsic value, as they had no oil value whatever.

---

[4]op. cit.

In the western part of Warren County there were two causes of inflation, the deep sand below the Shale and the shallow gusher sand, the latter probably having the greater effect upon inflation. Wells blowing in at several hundred to a thousand barrels per day at a depth of only 450 feet, on an average, with the possibility of the deeper sands undetermined caused acreage everywhere in the boom area to sell at very high figures. Although the shallow sand wells do not hold up long, many made money from their investments but many more were far less fortunate, for the shallow sand is very spotted and in some localities the well that came in so big was gone almost as quick. In many areas deepening of the wells to the Niagaran sand resulted in additional loss as oil from that horizon is restricted to certain areas. In the areas south of Bowling Green the life of the shallow wells is short but in the Davenport section and in the Whittaker pool some of the wells have held up very good considering their depth and the character of formation from which the oil comes. Drilling for the shallow St. Louis oil can never be considered on a business basis as it is purely a gamble.

In drilling for the Niagaran oil a consideration of economic factors are pertinent. If any estimate can be made before drilling from geologic structure or from prevailing sand condition, regarding the probable size of the well, then by computing the cost of the completed well an estimate can be made as to how long it will require for the production to pay for the cost of the well and the acreage that well will drain. A well 1,000 feet deep will cost, at the present price of drilling and supplies, between $6,000.00 and $6,500.00 on the pump; a well 1,300 feet deep, which would be on the hills in the highland area, will cost over $8,000.00 on the pump. The oil west of Bowling Green is over 38 degrees Baume gravity which classifies it as Somerset Light for which is paid in the field $4.18 (market price $4.50 less 32c pipe line charge). At these figures a well must have an average daily production of eight barrels, pumping 25 days per month, to pay the royalty, a moderate overhead expense, and the actual cost of a 1,000 foot well

in nine months' time; for the 1,300 foot well it would require twelve months. A well to average eight barrel per day for a year must come in flush several times this amount, in this character of sand, and the pay must be more than a few feet thick.[5] It would be most interesting to find out the number of producing wells in the county and divide into the production to determine the average size of all the wells. Some production figures are given at the end of this report but the actual number of wells on properties with pipe line connections is not known. The number on December 31, 1920, however, cannot be less than 200 and probably many more, most of which are in the Bowling Green section. This will include both shallow and deep sand wells.

The field is too young to furnish such data as is necessary in the construction of decline and future production curves. Enough was said regarding the shallow St. Louis sand to show that the decline of the wells is precipitous. However, from the very nature of the occurrence of these pools nothing of any detailed value could be obtained from production data which would be of any working value for the field as a whole. In the Niagaran sands the decline of wells is more normal. The writer has no figures of his own but was furnished the decline curve on one property in the Davenport section which is well located structurally and under which the sand condition is uniform. These figures showed a decline of approximately 50% in the first nine or ten months of production run through the pipe line, with developments progressing the entire period. The writer is not so optimistic as to believe that all leases will show such a small rate of decline as the example cited.

Warren County is well supplied with pipe line facilities although some of the wells ahead of general development work are not yet reached by any of the carriers. The Indian Refining Co., whose refinery is at Lawrenceville, Illinois, is the

---

[5]Since the preparation of this report Somerset Light has been reduced three times and is now $3.75, February 1, 1921. The nine and twelve month periods must be revised proportionately for wells drilled during the period this lower price prevails which will probably be for only a few months. On February 4, another cut of 75c brought Somerset Light down to $3.00.

largest pipe line carrier in Warren County. Others are Western Kentucky Pipe Line Producing & Refining Co., American Pipe Line & Refining Co., Petroleum Refining Co., Texas Shell Pipe Line Co., Eastern Gulf Oil Co., and Stoll Oil Refining Co. The oil is run into storage tanks at the loading racks or some other convenient place and shipped by tank cars to the refineries.

There has been talk for the past year and a half of building a refinery at Bowling Green, and several companies have made preliminary plans for such construction, but to date nothing more than buying sites has been done although claim is made that the material for the refinery projected by the Western Kentucky Pipe Line Producing & Refining Co. has been ordered.

There are four oil well supply houses, a few other dealers where oil well supplies can be purchased or ordered, and several tool and machine shops in Bowling Green, ample to supply the needs of the field, if the material is available from the manufacturer. Work has been retarded but not greatly handicapped during the past year by scarcity of supply material.

A large part of the drilling is done by gasoline tractor machines of which the Star, Sparta, Keystone, and Cyclone types, good for depths of from 1,000 to 2,000 feet, depending upon the size of the machine, are the most popular. They are easily moved and quickly rigged up, use fuel that is always available and easily transported, require very little water for drilling, and are comparatively safe from igniting a sudden flow of oil or gas. For most of the deeper wells steam rigs are used, the Star, Parkersburg, and National being the most popular. A few Standard rigs dot the area and add to the picturesqueness of the scene.

From the Green Hill area on the east to the Highland area on the west hard rock roads good the year round serve as the arteries of transportation from Bowling Green, which is the hub of the oil industry of Warren County. The contour of the country east of the Highland area and in which 95% of the development is confined is rolling and the cost of devel-

opment thereby lessened. The climate in general is not severe in either winter or summer and there need be no great curtailment of operations during the winter months.

Most of the development to date was done by the individual operator and small company as there are only a few of the larger organizations operating in Warren County. Development in the deeper areas has already reached the stage, viewed from an economic standpoint, where it is a company proposition.

DETAILED WELL RECORDS

The few well records given below are typical of the different sections in Warren County. Some are detailed logs, others simply show the depths to and through the Devonian Black Shale and the record of the oil sand. The oil analyses cover the various oils found in the county and the pipe line runs show the rate of progress in the development of the industry.

BEN F. HEWITT NO. 1. HARDCASTLE DISTRICT.

Red clay	0– 20
Lime, hard	20– 80
" hard, gray	80–180
" soft, gray, sandy (gas)	180–185
" hard, white	185–200
" soft, sandy	200–205
" hard, white	205–345
" sandy, white	345–400
" soft, green (New Providence)	400–440
Shale, black (Devonian)	440–492
Lime, hard, black	492–500
" gray sand	500–503
" sand, hard, white	503–510
" sand, hard, brown	510–522
" hard, gray	522–525
" soft, coarse, gray	525–532
" sand, soft, brown	532–542
" soft, coarse, gray	542–554
" sand, soft, brown	554–563
" total depth	563–568

JOE SHIPLEY NO. 1. CEMETERY PIKE, 2 MILES NORTHEAST BOWLING GREEN.

Clay	0– 32
Lime, yellow	32– 38
" white	38– 83
" gray—water	83– 95

Lime, brown—sulphur water at 162	95–239
black sulphur water at 181	
" hard, brown, sandy	239–258
Shale, hard, brown	258–267
Lime, brown	267–310
Soapstone	310–316
Lime, blue	316–333
" blue, (gas at 365)	333–375
" white, sandy (show oil at 384)	376–390
" blue (gas at 408 and 550)	390–638
Shale, black (Devonian)	638–705
Lime, cap	705–709
Sand, white	709–720
Lime and sand, hard, gray	720–742
Lime, sand, brown (show of oil)	742–745
" blue	745–749
" gray and gritty	749–771
" soft, gray	771–775
" soft, blue (show oil at 780)	775–806
" gray and sandy	806–820
" blue total depth	820–839

GRAHAM NO. 1, RICHARDSVILLE PIKE, 3 MILES NORTHWEST BOWLING GREEN.

Lime	0– 682
Shale, black (Devonian)	682– 767
Lime, gray	767– 783
" sand, white (oil odor)	783– 795
" sand, brown (oil show)	795– 819
" gray	819– 856
" soft, gray (show)	856– 876
" light gray	876– 902
"	902–1075
"	1075–1086
" sand, brown (oil odor)	1086–1121
" dark	1121–1130
Fresh water 40–60; Sulphur water	210– 225

J. B. SUMPTER NO. 1, ONE MILE SOUTH BOWLING GREEN.

Lime, (black sulphur water at 240)	0– 777
Shale, black (Devonian)	777– 837
Lime, brown and gray	837– 932
Red rock	932– 937
Lime, (show oil)	937– 943
Lime, gray and blue	943–1005

C. G. DAVENPORT NO. 1. (DR. RIGGS) WINLOCK BEND.

Sandy loam	0– 14
Lime, white (water)	14– 30
Sand, caving	30– 48

Lime, blue	48–	63
Mud cave	63–	66
Lime, gray	66–	91
" white	91–	181
" brown	181–	240
" blue	240–	244
" black	244–	251
" gray	251–	347
" shaley	347–	367
" gray	367–	473
" blue	473–	480
" gray	480–	616
" brown	616–	623
" gray	623–	763
Shale, black (Devonian)	763–	852
Lime, gray	852–	864
" white	864–	876
" brown	876–	904
" gray	904–	927
" gray pay sand	927–	943
" blue	943–	951

J. T. Hunter No. 1. Morgantown Pike, 3 Miles West Bowling Green.

Show oil, St. Louis sand		424
Shale, black (Devonian)	795–	870
Lime, gray, oil and gas	941–	947
Red rock	964–	966

Elrod No. 1, Five Miles South Bowling Green (Bailey Pool District)

Clay and boulders	0–	18
Lime, hard, gray	18–	38
" hard, white (crevice at 129)	38–	134
" blue	134–	138
" white	138–	140
" blue	140–	194
" brown	194–	270
" and sand, hard, white	270–	290
" soft, gray	290–	298
" hard, gray	298–	302
" sand, soft	302–	320
" gray, (probable oil sand)	320–	336
" gray, sandy	336–	365
" brown (probable oil sand)	365–	391
" gray, sandy and black slate	391–	416
" and sand, gray	416–	428
" hard, white	428–	442
" blue, hard	442–	470

Lime, black	470– 485
" soft, black	485– 542
Slate, black	542– 574
Lime, blue	574– 589
" black and hard sand	589– 639
" and sand	639– 654
Shale, brown and sand, hard (Devonian)	654– 677
" black	677– 725
Lime, gray	725– 733
" and sand, brown	733– 745
" and sand, white	745– 769
" brown, sandy	769– 773
" gray	773– 807
" and sand	807– 815
" and sand, brown	815– 835
" gray	835– 863
Shale, black	863– 895
Lime, brown, sandy	895– 899
" black	899– 927
" salt sand (filled in casing)	927– 931

DAVENPORT No. 11, BIG JACK OIL CO. 4 MILES WEST BOWLING GREEN.
Aneroid elevation, 570 feet.

Black Shale	919–1004
Oil sand	1089–1107

DAVENPORT No. 15, BIG JACK OIL CO.
Aneroid elevation, 444 feet.

Black Shale	785– 870
Oil sand	960– 967

WALLER No. 1, HEAD OF WINLOCK BEND, 5 MILES NORTHWEST BOWLING GREEN. Elevation about 460 feet.

Black Shale	755– 845
Lime	845– 925
Oil sand	925– 929

Fresh water at 250 feet.
Salt water at 375 feet.

MORRIS No. 1, GLEN LILLY PIKE, 4 MILES WEST BOWLING GREEN.

Black Shale	855– 938
Oil sand, (Devonian)	978– 982
Oil show	998–1002
Oil sand, (Silurian)	1006–1026

JENNIE BRIGGS No. 2, MORGANTOWN PIKE, 4 MILES WEST BOWLING GREEN.

Black Shale,	968–1065
Oil show, (Devonian)	1102–1112
Oil sand, (Silurian)	1180–1190

Oil filled hole 1,075 feet.

JEFFERSON No. 1, MORGANTOWN PIKE, 4½ MILES WEST BOWLING GREEN.
Aneroid elevation, 570 feet.

Black Shale, (bottom)	– 990
Oil show	–1017
Oil sand	1090–1093
Oil sand	1105–1115
(Bottom hole)	–1136

JEFFERSON No. 2, MORGANTOWN PIKE.
Aneroid elevation, 684 feet.

St. Louis sand	671– 675

MAE PALMER No. 1, 1 MILE NORTHWEST JEFFERSON LEASE, MORGANTOWN PIKE, 5½ MILES WEST BOWLING GREEN.
Aneroid elevation, 580 feet.

Black Shale	928–1015
Oil sand, (Devonian)	1051–1061

J. JOHNSON No. 2, DAVENPORT OIL CO., BARREN RIVER PIKE, 4½ MILES NORTHWEST BOWLING GREEN,
Aneroid elevation, 500 feet.

Black Shale	865– 945
Oil sand	1030–1051

GEORGIA DAVENPORT No. 1, BARREN RIVER PIKE, 5 MILES NORTHWEST BOWLING GREEN.
Aneroid elevation, 721 feet.

Black Shale	1112–1204
Oil sand	1287–1301

BROWNFIELD No. 1, ESCARPMENT RIDGE 5 MILES NORTHWEST BOWLING GREEN. Aneroid elevation, 725 feet.

Black Shale	1076–1156
Oil sand	1260–1271

MANNING No. 1, RAYS VALLEY 6 MILES NORTHWEST BOWLING GREEN.

Black Shale	786– 863
Oil sand	965– 980
Salt sand, (water)	980– 982

BIDDLE No. 1, BROWNS LOCK, BARREN RIVER, 7 MILES NORTHWEST BOWLING GREEN.

Black Shale	945–1045
Oil sand, (Devonian)	1080–1106
Oil sand, (Silurian)	1150–1180
(Bottom hole)	–1206

DAVENPORT, (DR. RIGGS) WINLOCK BEND, BARREN RIVER.
Elevation about 445 feet.

St. Louis sand	407 -	415

TARRANTS No. 1, STEIN ET AL. 3 MILES NORTHWEST BOWLING GREEN.

St. Louis sand	450–	453

WHITTAKER No. 1, DIXIE HIGHWAY, 6 MILES SOUTHWEST BOWLING GREEN.

Brown sandy lime	443–	462
Brown lime	462–	478
Oil sand	47?	

CLARENCE WILSON, BORRONE No. 1, 3 MILES SOUTH BOWLING GREEN.

Lime, white	0–	14
" blue (water at 110)	14–	250
" white	250–	300
" blue	300–	428
" gray, oil sand	428–	440
" brown, very hard	440–	444
" best oil and salt water	444–	448

DETAILED ANALYSES.

DEVONIAN OIL.

Analysis No. 1.[6]

Laboratory No. G-3861—Petroleum labeled "Lessor (Dr.) Hunter. Lessee. Duplex Oil Co., 3 miles west of Bowling Green, Warren County, Ky. 960 feet, total depth." Received from W. R. Jillson, State Geologist, September 15, 1919.

Analysis.

Specific gravity 0.834 at 60° F., equivalent to 37.9° B.

Distilled below 150° C. (302° F.)	20.2%	(Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.)	32.0%	(Burning oil fraction)
Thick, brown tar	45.0%	
Loss in analysis	2.8%	
	100.0%	

The oil began to distill at 65° C. (149° F.).

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Sept. 19, 1919.)

SILURIAN OIL.

Analysis No. 2.[6]

Laboratory No. G-3865—Petroleum labeled "Fresh, green oil, Joe B. Sumpter, No. 1, Mrs. Gray, lessee, ½ mile west of Bowling Green, Warren Co., Ky. Oil at 880-900 ft., total depth, 920 ft. Oil horizon Niagaran. Collected by W. R. Jillson, Sept. 14, 1919." Received from W. R. Jillson, State Geologist, September 15, 1919.

---

[6]Analysis Nos.: 1, 2, 3, 4, 5, and 6 from Oil and Gas resources of Kentucky, by W. R. Jillson, first Ed., 1919, third Ed., 1920, pp. 35 and 36.

Analysis.

Specific gravity at 60° F., 0.865, equivalent to 31.9° B.
Distilled below 150° C. (302° F.) ..... 9.3% (Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.) 37.5% (Burning oil fraction)
Tarry residue 52.5%
Loss in analysis 0.7%

100.0%

The oil began to distill about 80° C. (176° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Sept. 19, 1919.)

MISSISSIPPIAN OIL.

Analysis No. 3.[1]

Laboratory No. G-3864—Petroleum, labeled "(d) Green oil, Maj. R. W. Covington, No. 1, 355 feet above shale, ½ miles southeast of Bowling Green, Warren Co., Ky. Sept. 15, 1919." Received from W. R. Jillson, State Geologist, September 15, 1919.

Analysis.

Specific gravity at 60° F., 0.854, equivalent to 33.9° B.
Distilled below 150° C. (302° F.) ..... 13.0% (Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.) 36.5% (Burning oil fraction)
Tarry residue 50.0%
Loss in analysis 0.5%

100.0%

The oil began to distill at 75° C. (167° F.).

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Sept. 19, 1919.)

DEVONIAN OIL.

Analysis No. 4.[1]

Laboratory No. G-3863—Petroleum labeled "Green oil, open steel tank. Horace Bohon, No. 1. A. Goldstein, lessee. 840 feet deep, below shale. 1 mile east of Bowling Green, Warren County, Ky. Collected by W. R. Jillson, Sept. 14, 1919." Received from W. R. Jillson, State Geologist, September 15, 1919.

Analysis.

Specific gravity at 60° F., 0.856, equivalent to 33.6° B.
Distilled below 150° C. (302° F.) ..... 13.0% (Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.) 36.5% (Burning oil fraction)
Tarry residue and loss by difference 50.5%

100.0%

[1]Oil and Gas Resources of Kentucky, by W. R. Jillson, first Ed., 1919, third Ed., 1920, pp. 36 and 37.

The oil began to distill at 70° C. (158° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Sept. 19, 1919.)

DEVONIAN—SILURIAN OIL.

Analysis No. 5.[8]

Laboratory No. G—3862—Petroleum labeled "Green oil from J. A. Hamilton & Co., Wayne O'Neil, lessee, ½ mile northeast of Bowling Green, Warren County, Ky. Oil horizon, Onondaga and Niagara limestones. Depth, 850 feet. Collected by W. R. Jillson, September, 14, 1919." Received from W. R. Jillson, State Geologist, September 15, 1919.

Analysis.

Specific gravity at 60° F., 0.856, equivalent to 33.6° B.		
Distilled below 150° C. (302° F.)	14.5%	(Gasoline fraction)
Distilled from 150° to 300° C. (302–572° F.)	34.5%	(Burning oil fraction)
Tarry residue	50.5%	
Loss in analysis	0.5%	
	100.0%	

The oil began to distill at 65° C. (149° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Sept. 19, 1919.)

MISSISSIPPIAN OIL.

Analysis No. 6.

Laboratory No. G-3851—Petroleum labeled "Green Oil. Waverly Stray horizon, above Black Shale, on Drake's Creek, Warren County, Ky. V. Humbrecht, lessee. Depth 115 feet. Collected by W. R. Jillson. Aug. 2, 1919." Sample a rather thin, green oil, dark brown by transmitted light.

Analysis.

Specific gravity by hydrometer at 60° F., 0.840, equivalent to 36.7° B.		
Distilled below 300° F.	20.0%	(Gasoline fraction)
Distilled between 300 and 572° F.	36.5%	(Burning oil fraction)
Residue of thick, brown oil	42.8%	
Loss of distillation	0.7%	
	100.0%	

Percentages by volume.

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter)

DEVONIAN OIL.

Analysis No. 7.[9]

---

[8]Oil & Gas Resources of Kentucky, by W. R. Jillson, first Ed., 1919, third Ed., 1920, p. 37.

[9]Analysis Nos.: 7, 8, 9, and 10 from Contributions to Kentucky Geology, by W. R. Jillson, Article XIV, The New Oil and Gas Pools of Warren County, Kentucky, p. 234. 1920.

Laboratory No. G-3888—Petroleum labeled "Green crude oil, Glen Lily Tract, C. L. Goodrum lease, 1 mile west of Bowling Green, Warren County, Ky. Collected by C. H. Scott, Jan. 1, 1920." Sample, thin, green oil, dark brown by transmitted light. Forwarded by W. R. Jillson, State Geologist, for analysis.

Analysis.

Specific gravity, 0.848, equivalent to 35.1° B.		
Distilled below 150° C. (302° F.)	21.5%	(Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.)	33.8%	(Burning oil fraction)
Thick green-brown tar	44.4%	
Loss in analysis	0.3%	
	100.0%	

Began to distill at 55° C. (131° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Lexington, Ky., Feb. 6, 1920.)

MISSISSIPPIAN OIL.

Analysis No. 8.

Laboratory No. G-3879—Petroleum labeled "Fresh natural flow of amber crude oil from the Jim Britt farm—Waverly sand—Warren County, Ky. Collected by W. R. Jillson, State Geologist, November 9, 1919." Sample, a thin, amber colored oil having a strong green fluorescence. When the bottle was uncorked a few small gas bubbles appeared in the liquid (temperature about 80° F.).

Analysis.

Specific gravity, 0.810, equivalent to 44.8° B.		
Distillate below 150° C. (302° F.)	25.0%	(Gasoline fraction)
Distillate from 150° to 300° C. (302-572° F.)	38.8%	(Burning oil fraction)
Pasty, green residue	34.4%	
Loss in analysis	1.8%	
	100.0%	

Began to distill at 40° C. (148° F.)

The residue after distillation still retained the strong, green fluorescence of the original oil. It partly solidified on cooling, apparently from the separation of solid paraffin.

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter)

MISSISSIPPIAN OIL.

Analysis No. 9.

Laboratory No. G-3880—Petroleum labeled "Fresh pumping olive-green crude oil from Sam Thomas Heirs, Waverly sand, Warren County, Ky. Collected by W. R. Jillson, State Geologist, November 9, 1919." Sample a thin, green oil, dark brown by transmitted light.

Analysis.

Specific gravity, 0.844, equivalent to 35.9° B.		
Distillate below 150° C. (302° F.)	20.0%	(Gasoline fraction)
Distillate from 150° to 300° C. (302-572° F.)	33.8%	(Burning oil fraction)
Thick, brown, oily residue	46.2%	
	100.0%	

Began to distill at 68° C. (199° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter)

MISSISSIPPIAN OIL.

Analysis No. 10.

Laboratory No. G-3881—Petroleum labeled "Fresh natural flowing crude green oil from Albert Covington lease, Warren County, Ky. Waverly sand producing. Collected by W. R. Jillson, State Geologist, Nov. 11, 1919." Sample a pint of thin, green oil, received November 24, 1919.

Analysis.

Specific gravity 0.8815, equivalent to 34.4° B.		
Distilled below 150° C. (302° F.)	14.5%	(Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.)	38.5%	(Burning oil fraction)
Green and brown, thick residue	46.5%	
Loss in analysis	0.5%	
	100.0%	

Began to distill at 70° (158° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter)

DEVONIAN OIL.

Analysis No. 11.[10]

Laboratory No. G-3875—Petroleum received October 1, 1919, by mail, from the Department of Geology and Forestry, Frankfort, labeled "Green oil from the Z. Moody lease, Hoge Oil & Gas Co., operators, near Green Hill, Warren Co., Ky. Oil horizon, Onondaga. Fresh oil, collected by W. R. Jillson, Sept. 26, 1919." Sample, a thin green oil, dark brown by transmitted light.

[10] A new and heretofore unpublished analysis.

Analysis.

Specific gravity, 0.832, equivalent to 38.3° B.		
Distillate below 150° C. (302° F.)	23.1%	(Gasoline fraction)
Distillate from 150° to 300° C. (302-572° F.)	32.5%	(Burning oil fraction)
Brown tar	41.9%	
Loss in analysis	2.5%	
	100.0%	

A. M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Lexington, Ky., October 2, 1919.)